



Factors effecting hamstrings to quadriceps peak torque ratio in volleyball players

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Abstract

The aim of this study was to analyze of hamstring to quadriceps peak torque ratio (H:Q) measured in isokinetic testing with respect to different angular velocities (60, 180, 300°/s), gender, dominant side and mode of contraction (concentric, eccentric) in volleyball players. Twenty male and ten female healthy volleyball players participated in this study. An independent t-test was used to compare the differences between gender. One-way analysis of variance test was conducted to test for differences by effecting factors. There was a statistically significant difference between dominant and non-dominant side in H:Q ratio at 300°/s in males ($p<0.05$). There was no statistically significant difference between dominant and non-dominant side in H:Q ratio between female and male volleyball players ($p>0.05$). There was no statistically significant difference between at 60-180-300°/s velocities by $H_{conc}:Q_{conc}$ contractions and at 60°/s by $H_{conc}:Q_{ecc}$ contractions for male and female's peak torques in dominant side ($p>0.05$). There was a statistically significant difference between at 60°/s by $H_{conc}:Q_{conc}$ and $H_{conc}:Q_{ecc}$ contractions for male and female's peak torques in dominant side ($p<0.05$). There was a statistically significant difference H:Q ratio obtained by concentric contraction between at 60-300°/s and 180-300°/s velocities ($p<0.05$), whereas there was no statistically significant difference between 60-180°/s in male and female's peak torques in dominant side ($p>0.05$). It was found in our study that H:Q ratio increases with increasing angular velocity. The findings of the present study indicated that angular velocity, type of contraction and leg dominance influence isokinetic strength profiles of male and female, consequently, muscular balance that is H:Q at the knee. This implies that isokinetic concentric knee strength plays more role in high intensity contractions and has more effect at high velocities of contraction in maximal performance.

Keywords: Hamstring quadriceps strength ratio; angular velocity; gender; dominant side; concentric; eccentric.

1. Introduction

Muscle strength is one of the key factors in successful sports performance and is an important indicator of the effectiveness of injury rehabilitation in athletes. One of the most commonly used methods to assess muscle strength balance between antagonist/agonist muscles is isokinetic testing (Holcomb et al., 2007). Isokinetic testing can be used to evaluate quadriceps and hamstrings muscle strength, providing a determination of the magnitude of torque generated, and subsequently, the hamstrings to quadriceps (H:Q) strength ratio (Orchard et al., 1997). H:Q isokinetic strength of agonist to antagonist knee muscles ratio has been used to examine the functional ability, knee joint stability and muscle balance between hamstrings and quadriceps during velocity dependent movements (Orchard et al., 1997; Aagaard et al., 1995). It has been found that athletes with a concentric H:Q ratio closer to 1.0 may have a reduced risk of hamstrings strain

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(Orchard et al., 1997). Even admitting the multifactorial origin of hamstring injury, epidemiological evidence highlights that poor eccentric muscular strength and muscular strength imbalance play a central role in targeted acute muscle injuries (Woods et al., 2004; Croisier et al., 2008). Imbalance between the knee flexors and extensors has been traditionally assessed by conventional concentric hamstrings/quadriceps ratio ($H_{conc}:Q_{conc}$) and functional eccentric hamstrings/concentric quadriceps ratio ($H_{ecc}:Q_{conc}$) (Camarda and Denadai, 2012).

The strength of hamstring and quadriceps muscles are vital for volleyball players for locomotion in the game. Previous research has consistently reported that concentric and eccentric strength of hamstring and quadriceps muscles may positively affect physical performance of volleyball players (Alexander, 1990). When the hamstrings act to extend the hip, muscle strains may occur using rapid alternations between concentric and eccentric contractions (Petersen and Holmich, 2005). Injury can occur during pivoting movements such as landing from a jump and sudden changes in direction in field soccer and court (volleyball and basketball) athletes (Griffin et al., 2000). Differences in age, gender, stature, body mass, dominant side, joint angular velocities, affecting muscle length and mode of contraction can be cause to injury (Bloomfield et al., 2007).

Isokinetic assessment can be used to measure torque values at several joints in the body; the knee is perhaps the joint most commonly tested. This assessment typically involves comparing the involved joint with the uninvolved joint (Jones and Bampouras, 2010). In the literature, muscle strength difference between dominant and non-dominant extremities was shown by isometric, isotonic (concentric-eccentric), isokinetic methods and functionally (Jones and Bampouras, 2010; Demura et al., 2010; Newton et al., 2006). On the other hand, a difference was not shown by isokinetic testing made at various angular velocities (Demura et al., 2010; Pietrosimone et al., 2012). Some studies have compared the H:Q ratio between involved and uninvolved limbs (Griffin et al., 2000; Li et al., 1996). Previous studies found no difference in H:Q ratio between the left and right legs in a general adult population (Calmels et al., 1997), or collegiate athletes (Rosene et al., 2001). It is worth noting that differences in H:Q ratio were found in studies including only females (Holcomb et al., 2007) or males (Voutselas et al., 2007) but not in studies where both genders were recruited (Calmels et al., 1997; Rosene et al., 2001). A higher H:Q ratio has been observed in the non-dominant (ND) leg for females (Holcomb et al., 2007) but the dominant (D) leg for males (Voutselas et al., 2007). These studies raise the question of whether gender influences the direction of differences in H:Q ratio. The discrepancy in the literature H:Q ratios, joint angular velocities, leg dominance, type of contraction and the potential influence of gender warrants further investigation. The aim of present study was to analyze of hamstring to quadriceps (H:Q) peak torque ratio measured in isokinetic testing with respect to different angular velocities, gender, dominant side and mode of contraction (concentric, eccentric) in volleyball players.

2. Methods

2.1. Subjects

Twenty male (mean age: 24.1 ± 2.6 years; mean body height: 182 ± 4.3 cm; mean body mass: 75 ± 10.1 kg) and ten female volleyball players (mean age: 22.8 ± 1.6 years; mean body height: 165 ± 7.4 cm, mean body mass: 56 ± 6.3 kg) with no apparent health problems participated in this study voluntarily. They were all nonsmokers. All the players were members of the same team and trained for two hours five days per week. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki. Experimental procedures were approved by Pamukkale University Ethics Committee. At the beginning of the study, subjects were informed about the possible risks and benefits of the study and gave their informed consent to participate in this study. The players did not participate in any other training or matches during the study.

2.2. Procedures

Anthropometric Measurements

The subjects were asked to have a light, standard breakfast in the morning of the day of the experiment, then to report to the exercise laboratory at 8 a.m. On entering the laboratory, body height (cm) and body mass (kg) measurements were taken for each subject. The body height of the volleyball players was measured using a stadiometer with the accuracy to 1 cm (SECA, Germany), while electronic scales (Tanita BC 418, Japan) accurate to 0.1 kg were used for body mass measurements.

Isokinetic Muscle Strength

Before the isokinetic test, subjects warmed-up on a cycle ergometer pedaling at a work rate of 20 watts at 50 rpm for 5-minutes. An isokinetic dynamometer (Cybex Humac Norm 770, USA) was used to measure knee flexion and extension torque. The test was performed in a seated position with hands gripping the handles at the sides of the chair. The test was performed in a seated position; stabilization straps were secured across the trunk, waist, and distal femur of the tested leg. Gravitational corrections were also taken into account for the effect of leg and dynamometer arm weight on moment measurements. The most prominent point of the femoral epicondyle on the lateral surface of the knee joint was aligned with the axis of rotation of the dynamometer. The shin pad was placed distally approximately two finger breadths above the lateral malleolus. The range of motion for the knee was from 90 degrees of knee flexion to 10 degrees of extension. Isokinetic concentric H_{conc} and Q_{conc} muscle strength tests were performed at 60°/s with 5 repetitions, 180°/s with 10 repetitions and 300°/s with 15 repetitions without gravity for both right and left legs. H_{conc} and Q_{ecc} was performed at 60°/s with 5 repetitions. Verbal encouragement was given to the subjects during the measurement. Before starting the test, subjects were allowed 5 trials. A 30 s time interval was provided between repetitions whereas a 2 min rest period was given between angular velocity tests (Tsiokanos et al., 2002).

2.3. Statistical Analysis

Dominant leg values was used to compare different angular velocities (60, 180, 300°/s), gender and mode of contraction (concentric, eccentric). The data are reported as means and standard deviations. An independent t-test was used to compare the differences between gender. One-way analysis of variance (ANOVA) with Post Hoc Tukey test was conducted to test for differences by effecting factors. The level of significance was set at $p < 0.05$. Data are presented as mean \pm SD.

3. Results

Male and female volleyball players' mean age 24.1 ± 2.6 ; 22.8 ± 1.6 years, body height 182 ± 4.3 ; 165 ± 7.4 cm and body mass were 75 ± 10.1 ; 56 ± 6.3 kg, respectively.

Hamstring and quadriceps muscles peak torques (Nm) evaluated at different angular velocities (60, 180, 300°/s) by H_{conc} : Q_{conc} contractions and at 60°/s by H_{conc} : Q_{ecc} contractions for male and female volleyball players in the study are displayed in Table 1.

Table 1. Peak torques (Nm) values of hamstring and quadriceps muscles measured with isokinetic testing at 60,180, 300°/s with Hconc-Qconc and at 60°/s with Hconc-Qecc for male and female

60 °/s		180 °/s		300 °/s		60 °/s		
Hconc-Qconc		Hconc-Qconc		Hconc-Qconc		Hconc-Qecc		
D	ND	D	ND	D	ND	D	ND	
Male								
Q	195.7±46.81	172.17±34.96	141.30±21.04	126.32±21.1	131.21±20.4	115.22±17.4	185.27±21.23	165.17±14.96
H	165.81±29.99	146.10±25.20	104.32±23.2	92.1±21.03	93.4± 20.46	80.11±16.13	182.47±32.30	168.23±22.46
Female								
Q	151.19±20.22	145.11±53.2	109.32±23.5	99.02±21.12	85.15±17.12	79.02±12.11	145.01±13.45	122.11±53.2
H	80.41±26.41	69.55±25.32	65.55±15.12	53.25±12.08	56.03±13.22	40.14±10.04	72.04±10.12	51.11±53.2

H: hamstring; Q: quadriceps; D: dominant; ND: non-dominant; conc: concentric; ecc: eccentric
Values are given as mean ± SD

All results are summarized as follows:

a) Comparisons of measurements between dominant and non-dominant side

- There was a statistically significant difference between dominant and non-dominant side in H:Q ratio at 300°/s in males ($p < 0.05$) (Table 2).
- There was no statistically significant difference between dominant and non-dominant side in H:Q ratio between female and male volleyball players ($p > 0.05$) (Table 2).

b) Comparisons of measurements between gender (male/female)

- There was no statistically significant difference between at 60-180-300°/s velocities by $H_{conc}:Q_{conc}$ contractions and at 60°/s by $H_{conc}:Q_{ecc}$ contractions for male and female's peak torques in dominant side ($p > 0.05$) (Table 2).

c) Comparisons of measurements between mode of contraction (concentric/eccentric)

- There was a statistically significant difference between at 60°/s by $H_{conc}:Q_{conc}$ and $H_{conc}:Q_{ecc}$ contractions for male and female's peak torques in dominant side ($p < 0.05$) (Table 2).

d) Comparisons of measurements between different angular velocities (60, 180, 300°/s)

- There was a statistically significant difference H:Q ratio obtained by concentric contraction between at 60-300°/s and 180-300°/s velocities ($p < 0.05$), whereas there was no statistically significant difference between 60-180°/s in male and female's peak torques in dominant side ($p > 0.05$) (Table 2).
- It was found in our study that H:Q ratio increases with increasing angular velocity.

Table 2. Values for H:Q ratio at differences by effecting factors

	Velocity	Dominant leg (Nm)	Non-dominant leg (Nm)	P
Male	60°/s Hconc:Qconc	0.63 ± 0.07 [¥]	0.58 ± 0.08	0.03*
	180°/s Hconc:Qconc	0.75 ± 0.13 ^{&}	0.72 ± 0.13	0.01*
	300°/s Hconc:Qconc	0.86±0.31 ^Δ	0.79±0.18	0.01*
	60°/s Hconc:Qecc	0.56 ± 0.04 ^Ω	0.62±0.15	0.02*
Female	60°/s Hconc:Qconc	0.54 ± 0.07 [¥]	0.57 ± 0.12	0.01*
	180°/s Hconc:Qconc	0.65 ± 0.17 ^{&}	0.64 ± 0.12	0.02*
	300°/s Hconc:Qconc	0.71±0.10	0.66 ± 0.11	0.73
	60°/s Hconc:Qecc	0.51 ± 0.04 ^Ω	0.71 ± 0.13	0.02*

&: 180-300°/s; ¥: 60-300°/s
^{*}: Significant differences between male and female volleyball players
^Δ: Significant differences between dominant and non-dominant H:Q ratio
^Ω: Significant differences between 60°/s Hconc:Qconc and 60°/s Hconc:Qecc
^{*}p< 0.05

4. Discussion

It was found in our study that H:Q ratio increases with increasing angular velocity. Values of muscle strength (torque) for knee flexors and extensors were higher in male athletes at 60, 180, 300°/s compared to females. Greater quadriceps muscular strength of males and flexors in the dominant side may explain H:Q difference. Similarly with our results, in their review Hewett et al. (2008) demonstrated significant changes in H:Q ratio with increased isokinetic velocity in male and female athletes. Typical concentric H:Q ratios in healthy subjects range from 0.5 to 0.8, with a higher ratios at faster angular knee velocities during isokinetic testing (Orchard et al., 1997; Magalhaes et al., 2004).

The execution of action depends on the coordination of the segmental actions of the human body, which is determined by the interaction between the muscle forces (Newton et al., 2006). Differences in age, gender, stature, body mass, dominant side, joint angular velocities, type of contraction could affect muscle strength. The H:Q peak torque ratio has received a lot of attention regarding its use to quantify muscular imbalance as well as rehabilitation and physical conditioning (Kong and Burns, 2010). In addition, it was demonstrated that an imbalance in H:Q ratio correlates with a greater incidence of lower extremity injury (Bennell et al., 1998). When setting rehabilitation goals, it may be appropriate to adjust the H:Q ratio and leg strength compared to the uninvolved leg.

Side-to-side differences in muscle strength typically are expressed as differences between dominant and non-dominant sides (Calmels et al., 1997; Rosene et al., 2001; Magalhaes et al., 2004) particularly in uninjured subjects. In our study we found that there was a statistically significant difference between dominant and non-dominant side in H:Q ratio at 300°/s in males. There was no statistically significant difference between dominant and non-dominant side in H:Q ratio between female and male volleyball players. Results isokinetic test made at 60, 180, 300°/s for knee flexors and H:Q peak torque ratio were found to be higher in the dominant extremity, on the other hand data were found to be indifferent between extensors strength (torque). It might be likely that athletes' training routines are responsible for this muscular imbalance, which in turn may be beneficial for improvements in sport performance. In the literature, muscle strength difference between dominant and non-dominant extremities was shown by isometric, isotonic, isokinetic

methods and functionally (Jones and Bampouras, 2010; Demura et al., 2010). In one study both field and court players demonstrated less than 15% discrepancy between dominant and non-dominant leg muscle strength during isokinetic test and no significant difference between the two groups (Roy et al., 2012). Rosene et al. (2001) found that side to side muscle strength difference was not demonstrated between athletes of the different sports.

In our study we found that there was no statistically significant difference between at 60-180-300°/s velocities by $H_{conc}:Q_{conc}$ contractions and at 60°/s by $H_{conc}:Q_{ecc}$ contractions for male and female's peak torques in dominant side. At slower testing velocities, no differences in isokinetic H:Q peak torque ratio between the sexes were observed. However, with increased angular velocity, significantly greater H:Q peak torque ratios were observed in men than in women in this study. Renstrom et al. (2008), found that H:Q peak torque ratios tend to be higher in men than in women. In contrast, Aagaard et al. (1995) did not report differences in H:Q peak torque ratio at different isokinetic test velocities. In addition to gender related differences, other subject characteristics such as age and training may be more relevant for the explanation of discrepancies in H:Q ratio in the literature (Kong and Burns, 2010).

The strength of hamstring and quadriceps muscles are vital for volleyball players for locomotion in the game. H:Q ratio of strength of agonist to antagonist knee muscles has been used to examine the functional ability, knee joint stability and muscle balance between hamstrings and quadriceps during velocity dependent movements (Hewett et al., 2008). It was found in our study that there was a statistically significant difference H:Q ratio obtained by concentric contraction between at 60-300°/s and 180-300°/s velocities ($p < 0.05$), whereas there was no statistically significant difference between 60-180°/s in male and female's peak torques in dominant side. The increased H:Q ratio with increased velocity is consistent with the findings of Kannus (1988) and with those of Croce et al (1996) who reported increases in the H:Q ratio from $61.0 \pm 14.3\%$ at 60°/s to $62.0 \pm 14.7\%$ at 90 °/s in nondisabled, sedentary controls. Comparatively, our subjects had H:Q ratios of 84.6% at 60°/s, 73.7% at 180°/s, and 70.9% at 300°/s for men and 52.9% at 60°/s, 59.6% at 180°/s, and 65.8% at 300°/s for women at dominant side. These ratios are lower than those reported by Bennell et al (1998) at 60°/s and 180°/s. Knapik et al. (1991) studied only female athletes, while Bennell et al. (1998) studied only males, but both found higher H:Q peak torque ratios at higher isokinetic test velocities.

Zachry et al. (2005) was proposed that verbal instructions could influence maximal muscular force production or endurance tasks. The benefits of externally verbal instructions have been demonstrated in the acquisition and performance of sports skills. Similarly, in our study verbal encouragement was given to the subjects during the measurement. Wording the instructions given to learners in a way that they direct attention to the movement effect, rather than to their movements, has been found to enhance the accuracy of golf shots, volleyball serves, soccer kicks and basketball free throws (Wulf et al., 2002).

In our study we found that there was a statistically significant difference between at 60°/s by $H_{conc}:Q_{conc}$ and $H_{conc}:Q_{ecc}$ contractions for male and female's peak torques in dominant side. H:Q ratio measured by concentric/concentric and concentric/eccentric contraction showed that it can vary depending on the mode of contraction. Relation between force and velocity was explained long ago (Aagaard et al., 1995). The H:Q ratio has conventionally been expressed as concentric hamstrings to quadriceps strength and recently as eccentric hamstrings to concentric quadriceps strength (Aagaard et al., 1998). Eccentric hamstring activity has also been reported in a variety of activities in which knee extension occurs (Aagaard et al., 1995; Li et al., 1996) such as the control of running activities and for stabilizing the knee joint during foot contact with the ground (Rahnama et al., 2003). Yapıcı et al. (2016) found a correlation between concentric contraction of hamstring and eccentric contractions of quadriceps for jump related muscle strength. Notably, both Q_{ecc} and H_{conc} were found as predictive factors for counter movement jump (CMJ) and squat jump (SJ).

5. Conclusion

The findings of the present study indicated that angular velocity, type of contraction and leg dominance influence isokinetic strength profiles of male and female, consequently, muscular balance that is H:Q at the knee. This implies that isokinetic concentric knee strength plays more role in high intensity contractions and has more effect at high velocities of contraction in maximal performance.

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